Journal & Proceedings of the Royal Society of New South Wales, Vol. 141, p. 33–37, 2008
ISSN 0035-9173/08/020033–5 $4.00/1

Searching for ETI

RAGBIR BHATHAL

Abstract: The search for extraterrestrial intelligence is a scientific experiment which has been pursued for the last forty-five years. Over one hundred searches (ranging from one-off to sporadic and continuous) in both the microwave and optical regions of the electromagnetic spectrum have been carried out during this time. To date no ETI signals with the required signature have been discovered. This paper discusses some of the most significant searches and future directions in the search for extraterrestrial intelligence.

Keywords: ETI search strategies; ETI radio searches, Nanosecond pulses.

INTRODUCTION

The scientific search for extraterrestrial intelligence or SETI for short had its beginnings in the second half of the 20th century. In its early years the SETI program was plagued by questions of its validity as a scientific discipline. In fact, several members of the IAU Commission 51 were extremely critical of it. However, this has not stopped astronomers and astrobiologists from continuing the search for ETI in the electromagnetic spectrum.

GENESIS AND RADIO SEARCHES

The genesis of the modern SETI experiment was a seminal paper published by Cocconi and Morrison in 1959 (Cocconi and Morrison 1959) which suggested that radio telescopes should be used to look for signals at 1420 MHz (21 cm line) from seven sun-like stars within 15 light-years from the Sun. Within five years of the publication of this paper in the scientific press several lines of inquiry were established, viz: radio, optical, probes and biospheres. The emphasis placed on each of these methods was different.

The first radio search was conducted in 1960 by Drake in his now famous Project Ozma experiment (Drake 1961). The search failed to detect any signals from ETI civilisations

Four search strategies emerged (brief directed searches on available telescopes, piggyback searches which operated on telescopes being used for mainstream astronomy programs, dedicated searches and distributed searches by amateur SETI astronomers worldwide) after Drake's historic search. Both targeted and sky survey techniques have been used. The microwave searches have mainly been carried out on so called 'magic' frequencies (the 21 cm hydrogen line) with frequency resolutions varying from Megahertz to a few hundredths of a Hertz. The size of the radio telescopes has ranged from a few metres in diameter to the giant 305 metres instrument at Arecebo, the world's most sensitive and largest radio telescope.

About ten years after Project Ozma the first dedicated search in the USA for ETI signals was carried out under the direction of J. Kraus and R. Dixon at the University of Ohio. Although a number of candidate signals were detected during the course of the program, including the now famous Wow! signature, however, none of them were reconfirmed. The Ohio SETI group is now engaged in the design and construction of the Argus radio telescope. The Argus telescope which is designed to cover most of the sky at L-band consists of a planar array of mass produced omnidirectional antennas which are capable of 'seeing' in all directions of the sky at once. (Ellingsen et al. 2008).

The Harvard University group began their SETI searches with suitcase SETI which was later reconfigured as Project Sentinel in 1983. Suitcase SETI was a portable high-resolution spectrometer developed in 1978–82 and connected to the Arecibo radio telescope in March 1982. It was further developed into META (Megachannel Extraterrestrial Assay), META II and BETA. All these instruments were used to carry out all-sky surveys. The Harvard BETA instrument scanned the waterhole region with a 250 million channel receiver, each channel being 0.5 Hz wide. It used a 26 metre dish and scanned 68 per cent of the celestial sphere four times from October 1995 until March 1999 when the antenna's mounting broke in a windstorm. The telescope was dismantled in May 2007.

The negative results of the BETA search has allowed the Harvard group to set some limits on the prevalence of transmitting civilisations albeit with certain qualifications (Leigh and Horowitz 2000). None of the archived candidates had the characteristics of an extraterrestrial signal.

The SERENDIP (acronym for the Search for Extraterrestrial Radio Emissions from Nearby Developed Intelligent Populations) program has its home at the University of California and began operations in the 1970s. It was designed for use in piggy back mode. This was to get around the difficulty of not being able to get telescope time on major radio telescopes. The SERENDIP equipment at the University of California has undergone a number of evolutions, viz: SERENDIP I, SERENDIP II, SERENDIP III, SERENDIP IV and SERENDIP V. Each stage in the evolution has been more complex and sensitive than the previous one. The number of channels has increased at each stage of its development. SERENDIP IV was designed and run by Werthimer, et al. (1997) in piggyback mode as an all-sky survey on the Arecibo telescope. The survey used a 168 million channel FFT spectrum analyser to search for narrow band radio signals in a 100 MHz band centred at the 21 cm hydrogen line. The system had a 1.7 second integration time, 0.6 Hz resolution and a sensitivity of 10^{-24} W/m^2. The latest SERENDIP V is much more sensitive and it can listen to 300 MHz of radio channels at once instead of 100 MHz. It piggy-backs on the Arecibo telescope and takes advantage of its 7-beam focal plane array. It uses coincident detections to discriminate against interference.

Project Phoenix is the flagship of the SETI Institute in California. It was the largest, most sensitive targeted search program. Project Phoenix's first major search program was carried out at the Parkes radio telescope in Australia from 2nd February to 6th June 1995 (Tarter 1997). The Parkes and Mopra antennas were used as a pseudo-interferometer to search for ETI signals from 209 solar-type stars in the Southern Hemisphere over the frequency range 1,200 to 3,000 MHz. The sensitivity of the observations was sufficient to rule out any narrow band transmitters stronger than 5×10^{12} Watts broadcasting during their observations.

Although no ETI signals were found the strategy of using two widely separated antennas linked together as a pseudo-interferometer proved to be an extremely effective way to discriminate against RFI.

After the Parkes survey, Project Phoenix used the Arecibo telescope to search for ETI signals from a list of 1000 promising stars within 200 light years of the Sun. The Arecibo telescope was paired with the Jodrell Bank telescope in the UK. The search frequency spanned the range 1,200 to 3,000 MHz and surveyed about 500 nearby stars. It concluded its nine year search in 2004. Project Phoenix has been replaced by a new program based on the Allen Telescope Array (ATA). It will use 350 mass-produced small dishes (6 m in diameter) to form a collecting area of 10,000 square metres and target 100,000 candidate stars for intensive SETI observations (Tarter 2001). In October 2007 the first 42 dishes began science observations.

Still in the planning stages is the development of the multinational Square Kilometre Array (SKA) which will be used for mainstream astronomical research and also for the cradle of life program which will have the SETI search as one of its components (Tingay 2008, Bhathal 2005). The main scientific thrust of the array is to study the structure of the early universe prior to the formation of galaxies with the use of highly red-shifted HI. It will also have the ability to synthesize up to 100 pencil beams simultaneously. Even if just ten beams were used for the SETI program it will be able to cover a million stars in a targeted search over a period of about ten years.

OPTICAL SETI

A quick calculation shows that the apparent magnitudes of the ETI star and the ETI CW laser at a distance of 10 light years from us would be 2 and 21. The laser source would just be picked up by the 200 inch telescope at Mt Palomar Observatory. However, it must be pointed out that in this scenario the host star would swamp the light from the laser. For the experiment to work we need to have more powerful lasers. Pulsed solid-state lasers have achieved terawatts, albeit for a few nanoseconds. The National Ignition Facility at the Lawrence Livermore National Laboratory could deliver 500 TW pulses lasting 3 to 5 ns.

These developments in laser power have opened the way for a consideration of the optical SETI search strategy as a viable search strategy (Bhathal 2000). However, the breakthrough came with the discovery a few years back of a long forgotten paper by Monte Ross who had been working on laser communications for the Research and Development Department at Hallicrafters Co., Chicago. In his now classic 1965 paper (Ross 1965), he noted that information theory shows that at optical frequencies, narrow pulse, low-duty cycle systems can convey more information per received signal photon than radio waves. Calculations show that a pulsed laser beacon will outshine its host star by four to seven orders of magnitude depending on the output of the laser. For example, for a pulsed laser beacon system with a 1 Hz repetition rate and a peak power of 10^{18} W it can be shown that the magnitude of the ETI laser and the ETI star at a distance of 10 light years would be -15 and 2. Sources of these magnitudes can be easily picked up even by small telescopes.

Over the last seven years four new optical SETI projects have come on line, viz: the University of California's SEVENDIP (acronym for Search for Extraterrestrial Visible Emissions from Nearby Developed Populations) project, the Harvard University optical SETI project, the Lick Observatory optical SETI project and the University of Western Sydney's Australian Optical SETI (or OZ OSETI for short) project. All projects are based either on very fast photomultiplier tubes or avalanche photodiodes. The equipment uses a beam splitter to feed the light from the telescope onto a pair of very fast photomultiplier tubes or avalanche photodiodes. The signals are fed to a pair of high speed amplifiers, a pair of fast discriminators and a coincidence detector. All are searching for nanosecond pulses with specially built coincidence circuits to eliminate false signals and noise which can be attributed to scintillation in the photomultiplier glass from cosmic rays, ion feedback and radioactive decay of potassium (K40) located in the PMT glass. Background noise and interference from astrophysical phenomena and atmospheric and terrestrial sources have been found to be negligible in the optical SETI experiments conducted to date. Most of the interference has come from detector pathologies. In general, this has been eliminated by the use of two or three detector systems with coincident circuits or two telescopes with detectors wired up in coincident mode.

The University of California is searching in the 300–650 nm wavelength range with a 0.8 m automated telescope at Leuschner Observatory. Fast PMTs with a rise time of 0.7 ns are wired up in coincident mode. They are searching for signals from F, G, K and M stars, a few globular clusters and galaxies (Werthimer et al. 2001). The pulse search has examined about 700 stars with a dwell time of about two minutes a star. The experiment's sensitivity is 1.5E-17 W/m^2 for a one nanosecond pulse. To date they have found no ETI signals.

The Harvard University project was searching in the 160–850 nm wavelength range but centred on 420 nm. They were also targeting F, G, and K stars. Their detector system rode in piggyback mode on a radial velocity survey. They synchronized their observations with a group at Princeton University located about 200 km away with the use of GPS receivers to synchronize the detection of pulses within a microsecond over the millisecond delay between the two observatories. By 2004 they had made observations of over 6,000 stars but they did not find any ETI signals of the nanosecond pulsed variety (Howard, et al. 2004). The Harvard group has built a 1.8 m dedicated wide-field optical telescope with a fast pixelated photodetector for an all-sky survey. The telescope is essentially used as a photon bucket.

The Lick Observatory project uses a three detector system which has been designed to eliminate the incidence of false positive signals that have been observed on the University of California and Harvard University two detector optical SETI systems. The system uses fast PMTs with a spectral response from 300-850 nm. The device is mounted at the f/17 Cassegrain focus of the Lick Observatory's 1 m Nickel telescope.

The OZ OSETI project was built mainly with private sector funding. It is searching for signals from transmitters with peak instantaneous power greater than 10^{18} W. The search is conducted in the 300–700 nm range but centred on 550 nm. The equipment is wired up in coincidence mode to eliminate false signals. The OZ OSETI project is the only dedicated optical search in the Southern Hemisphere. To date 2,000 stars and 30 globular clusters have been searched for ETI signals. A FFT analysis of all the observations with MATLAB has provided negative results to date.

THE FUTURE

Over the last few years a number of strategies have not only been revisited and refined but new search strategies have been developed. All of them are in various stages of development.

Major developments in detector technology could enable pulsed IR searches. From the point of view of the transmitter, pulsed infrared SETI has a number of advantages, such as, greater signaling range, lower energy cost per photon and decreased stellar background. This search strategy will become feasible when affordable fast detectors become available.

Ross and Kingsley (2001) are planning the PhotonStar project which will be an optical version of the SETI@home project but with a difference. The project is aimed at 'amateur' optical astronomers who already posses a well equipped observatory. GPS technology will be used to obtain precise location and time information for the observatories located across the USA. Each observatory will have a turnkey detector module and the data from each observatory will be collected and integrated over the internet.

The OZ OSETI project is planning to build a dedicated one metre optical telescope to be financed mainly by the private sector. The initial design plans have been drawn up. The telescope will be used as a light bucket in transit mode and will be able to complete a survey of the southern sky in about 250 nights. The detector will be based on Hamamatsu's recently released multi-pixel photomultiplier tubes which have a quantum efficiency between 10 and 20% for 300–550 nm, a gain of 10^6 and a rise time of about 1 ns and FWHM of about 3 ns.

Over the next few decades a number of space telescopes will be launched by ESA and NASA. The space telescope programs offer a tremendous opportunity of carrying out an optical SETI search along with other astronomical programs. The Terrestrial Planet Finder is planned for launch in 2015. It will look for traces of early life in the infrared spectra of extrasolar planets. As currently envisioned it will also be sensitive to deliberate laser transmissions from technologically advanced civilisations. A kilowatt class laser with a 10 m beam director would produce a signal visible to TPF at a range of 15 pc that is distinguishable from astrophysical phenomena and noise (Howard and Horowitz 2001).

Far into the future is a proposal for a SETISAIL project proposed by Jean Heidmann and Claudio Maccone (1994). They based their arguments on the gravitational lens effect of the Sun, solar sail technology and the galactic belt of advanced life to launch an inflatable combined sail/radio telescope system at a 550 AU distance outside the solar system. The sail would be focused at Balaz's maximum where it will go through a 7000 light years long section of the belt of life. They even propose a launch direction at galactic longitude of 270 degrees and galactic latitude of 0 degrees. Because of rising radio interference it is envisaged that sensitive SETI observations will be difficult to be conducted from Earth within the next ten to twenty years. Thus, Heidmann (2000) has proposed the establishment of an observatory on the far side of the Moon. He has suggested that the observatory be located at the Saha crater because no Earth or geostationary orbit based radio emission can reach this site.

CONCLUSION

For SETI to succeed it is imperative the search strategies be broad and varied. The reason for this is that no one really knows what type of communicating device ETI civilisations will use to contact us. Although forty-five years of searching have been conducted it would appear that we have barely begun the search.

ACKNOWLEDGEMENTS

The author wishes to thank Stuart Kingsely and Monte Ross for helpful and stimulating discussions on the search for ETI.

REFERENCES

Bhathal, R., 2000. The case for optical SETI. *Astronomy & Geophysics* **41(1)** 25–26.

Bhathal, R., 2005. Policy: Australian astronomy looks forward. *Astronomy & Geophysics* **46(6)** 35–36.

Cocconi, G. and Morrison, P., 1959. Searching for interstellar communications. *Nature* **184** 844-846.

Drake, F., 1961. Project Ozma. *Physics Today* **14** 40–46.

Ellingson, S.W., Hampson, G.A., Childers, R.K., 2008. Argus: An L-band all sky astronomical surveillance system. *IEEE Transactions Antennas & Propagation* **56(2)** 294–302.

Heidmann, J., 2000. Recent progress on the lunar far side crater Saha proposal. *Acta Astronautica* **46** 661–665.

Heidmann, J. and Maccone, C., 1994. Astrosail and SETISAIL: two extrasolar system missions to the Sun's gravitational focuses. *Acta Astronautica* **32** 409–410.

Howard, A.W., Horowitz, P., Wilkinson, D.T., Coldwell, C.M., Groth, E.J., Jarosik, N., Latham, D.W., Stefanik, R.P., Willman, A.J. Jr., Wolff, J. and Zajac, J.M., 2004. Search for nanosecond optical pulses from nearby solar-type stars. *Astrophysical Journal* **163** 1270–1284.

Howard, A.W. and Horowitz, P., 2001. Optical SETI with NASA's terrestrial planet finder. Icarus **150(1)** 163–167.

Leigh, D. and Horowitz, P., 2000. Strategies, implementation and results of BETA. In "Bioastronomy '99: a new era in bioastronomy". Edited by G.A. Lemarchand and K.J. Meech. Astronomical Society of the Pacific, San Francisco. 459–465.

Ross, M., 1965. Search via laser receivers for interstellar communications. *Proceedings of the IEEE* **53(11)** 1780

Ross, M. and Kingsley, S.A., 2001. PhotonStar Project. In 'The search for extraterrestrial intelligence (SETI) in the optical spectrum III'. Edited by S.A. Kingsley and R. Bhathal. Proceedings of SPIE, Volume 4273, 110–118. Washington.

Trater, J., 1997. Results from Project Phoenix: Looking up from down under. In 'Astronomical and biochemical origins and the search for life in the universe'. Edited by C.B. Cosmovici, et al. Editrice Compositori, Bologna. 633–643.

Tarter, J., 2001. SETI 2020: a roadmap for future SETI observing projects. In 'The search for extraterrestrial intelligence (SETI) in the optical spectrum III'. Edited by S.A. Kingsley and R. Bhathal. Proceedings of SPIE, Volume 4273, 93–103. Washington.

Tingay, S., 2008. Square Kilometre Array. *Australian Physics* **45** 80–83.

Werthimer, D., Bowyer, S., Ng, D., Donnelly, C., Cobb, J., Lampton, M., and Airieau, S., 1997. The Berkely SETI program: SERENDIP IV instrumentation. In 'Astronomical and biochemical origins and the search for life in the universe'. Edited by C.B. Cosmovici, et al. Editrice Compositori, Bologna. 683–688.

Werthimer, D., Anderson, D., Bowyer, S., Cobb, J., Heien, E., Korpela, E.J., Lampton, M.L., Lebofsky, M., Marcy, G.W., McGarry, M. and Treffers, R., 2001. The Berkeley radio and optical SETI: SETI@home, SERENDIP and SEVENDIP. In 'The search for extraterrestrial intelligence (SETI) in the optical spectrum III'. Edited by S.A. Kingsley and R. Bhathal. Proceedings of SPIE, Volume 4273, 104–109. Washington.

Dr Ragbir Bhathal, OZ OSETI Project
School of Engineering, University of Western Sydney
Locked Bag 1797, Penrith South DC, NSW 1797, Australia

(Manuscript received 08.2008, accepted 09.2008)